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ASD TECHNICAL NOTE 61-117

PART III

16 260

MECHANICAL PROPERTIES
INFORMATION PROCESSING SYSTEM

Fatigue of Metals

LOW ALLOY STEEL

SECTION I

*Effect of Ultimate Tensile Strength
on the Fatigue Behavior of 4340 Steel*

Contract AF 33(616)-7238

February 1962

BELFOUR ENGINEERING CO.

SUTTONS BAY, MICHIGAN

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FOREWORD

The graphic displays of metals fatigue data presented in this report have been prepared by the BELFOUR ENGINEERING COMPANY under U.S.A.F. Contract No. AF33(616)-7238, S.A.1 (61-1094), and S.A.2 (62-479). This contract was initiated under Project No. 7381, "Development of a Materials Property Data Processing System", Task No. 73812. Administration of the project is under the direction of the Applications Laboratory, Directorate of Materials and Processes, Aeronautical Systems Division, Wright-Patterson Air Force Base, with Don M. Ingels, Lt/USAF acting as project engineer.

This report is one of a series being prepared for periodic dissemination.

ABSTRACT

The graphs presented herein display metals fatigue information from various sources of published and unpublished test reports which have been processed and regenerated through a semi-automatic data processing system. Each series or set of graphs contain descriptive information (legends) which identifies the material, test procedure, test conditions and the most significant test and/or material variables associated with the plotted data. The data displayed in each set of graphs is intended to answer very general "questions" and to serve as a guide to further investigation of specific areas within the subject presented.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:



D. A. Shinn
Chief, Materials Information Branch
Application Laboratory
Materials Central

TABLE OF CONTENTS

			Page
Introduction			1
Graphic displays of the effect of ultimate tensile strength on the fatigue behavior of AMS 6415 (AISI 4340) steel tested at room temperature with zero mean stress and rotary beam loading. (Results of tests conducted with stresses of other than zero will be displayed in a subsequent Section of this series of Technical Notes).			
<u>Graph No.</u>	<u>Specimens</u>		<u>Ultimate Tensile Strength, KSI</u>
	<u>Unnotched</u>	<u>Notched</u>	
1A	X		143 & 144
1B		X (2.6 K _t)	144
2	X		158
3A	X		160
3B		X (2.0 K _t)	164
4	X		171
5	X		188 & 189
6	X		191 & 192
7	X		236, 237 & 238
8	X		268
9	X		275
10	X		290
Reference List			25

INTRODUCTION

This is one of a series of reports presenting compilations of test results pertaining to fatigue of metals.

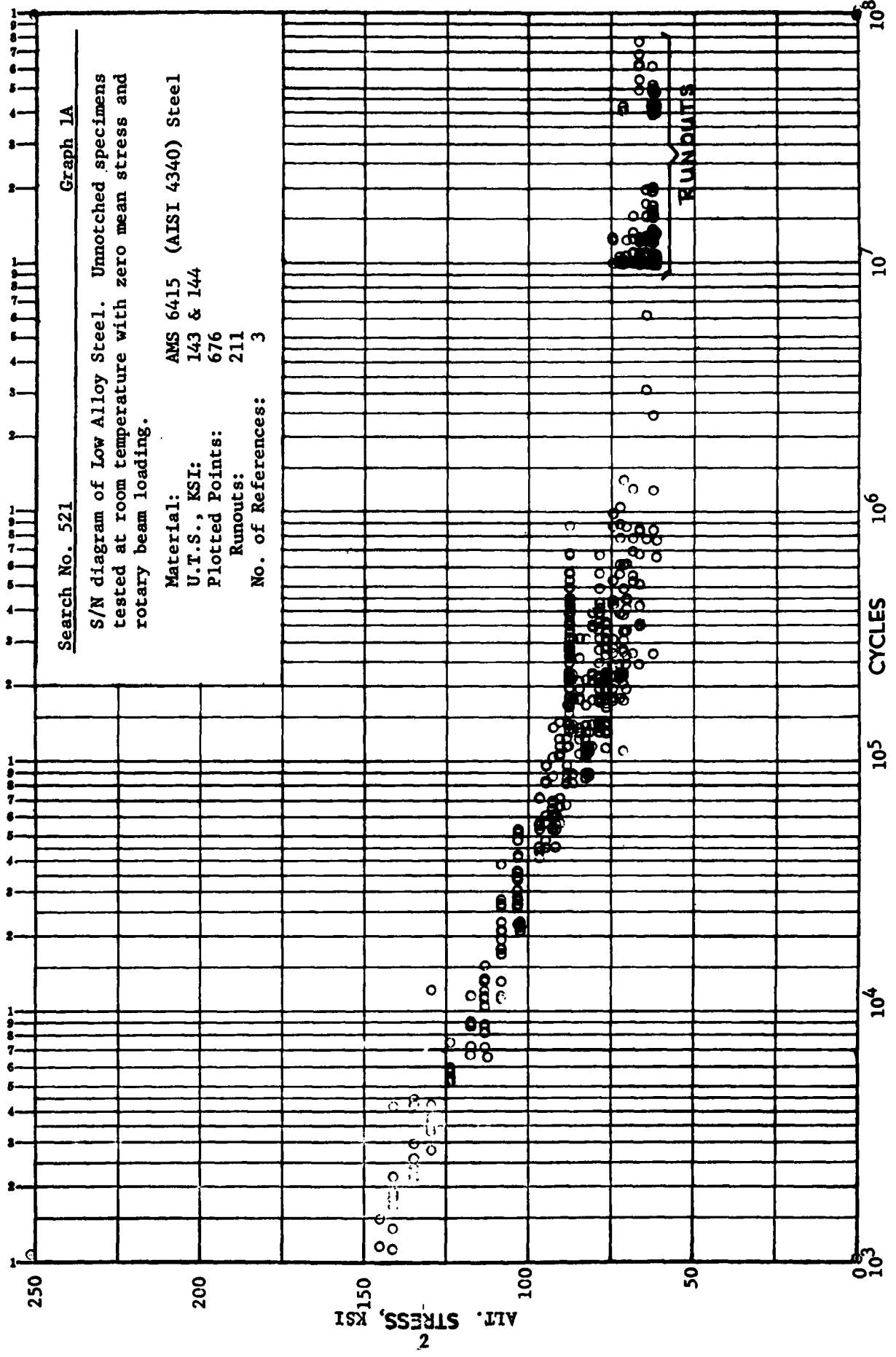
The information contained in each set of graphs is the result of a relatively general "question" asked of a semi-automatic data processing system which stores, processes and regenerates the information in the requested form. More specific and detailed presentations and analyses are usually possible. These are available upon request. The graphic form in which this information is presented is only one of various types of output of which this mechanized system is capable. Tabulations and listings may also be generated by the system.

These data are intended to assist in the determination of reliable and efficient materials properties. The information contained herein should be used with due consideration to applicable specifications and established organizational procedures.

All graphs are labeled with a "search number". These serve to identify a broad block of information associated with a particular (internal) data processing pattern. Graph numbers are assigned in sequence within any search for the purpose of separating and identifying sub-groups of useful information. There is no requirement for graphs in any number sequence to have any relationship other than being the product of the same search. Alphabetic characters following a common graph number are used to identify a series or set of graphs which are related. Subsequent graphs within a series (bearing a common graph number) are used to indicate effects and interactions associated with some obvious variables. The unlimited number of combinations available for display and analysis dictates that these presentations be limited to relatively general subject matter. Detailed studies can be performed on request.

A legend on each graph describes the material, test type and other variables necessary to identify the plotted data. Additional description of material, processing, and testing is provided by a Summary Data Sheet for each display of data. All references, identified by code numbers on the Summary Data Sheets, are completely identified on the Reference List which is the last page of the Technical Note.

AUTOMATIC DATA ANALYSIS



SUMMARY DATA SHEET
METALS FATIGUE TESTS

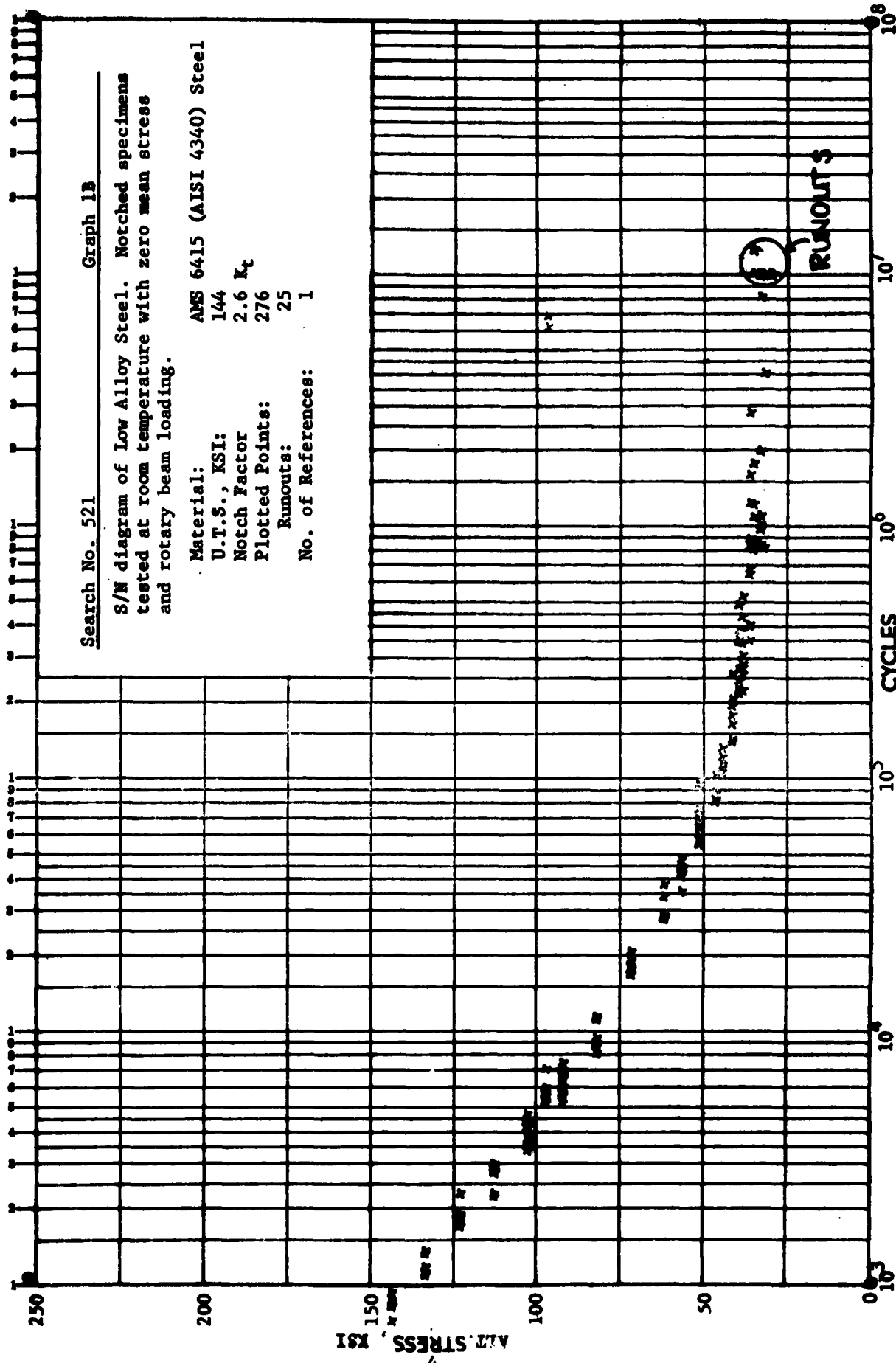
Search No. 521

Graph 1A

Reference Code Nos.:	* 001, 067 & 117		
Material:	AMS 6415 (AISI 4340) Steel		
Melting Practice:	Electric Furnace & Not Recorded		
Heat Treatment:	Normalized	1600°F, 1.5 Hr,	AC
	Austenitized	1525°F, 1.5 Hr,	OQ
	Tempered	1150°F, 4 Hrs,	AC
	Normalized	1600°F, 2 Hrs,	AC
	Austenitized	1500°F, 2 Hrs,	OQ
	Tempered	1150°F, 4 Hrs,	AC
	Normalized	1600°F, 4 Hrs,	AC
	Austenitized	1525°F, 2 Hrs,	OQ
	Tempered	875°F, 4 Hrs,	AC
	Stress Relieved	700°F, 2 Hrs,	
	F.C. to 300°F,	AC	
Yield Strength, KSI:	128 or 132		
Elongation:	20%, Gage not specified; 21%, 1" Gage; 21%, Gage not specified.		
Hardness :	R _c 30, 31, 32 or Not Recorded		
Surface Condition:	Mechanical Polishing		
Surface Finish:	5 Microinch		
Primary Fabrication:	Forged or Hot Rolled		
Secondary Operation:	Lathe Turned or Ground		
Specimen Type:	Unnotched bars over 0.125" thick		

*See Reference list for complete identification of reference documents.

AUTOMATIC DATA ANALYSIS



Search No. 521

Graph 13

S/N diagram of Low Alloy Steel. Notched specimens tested at room temperature with zero mean stress and rotary beam loading.

Material:

AMS 6415 (AISI 4340) Steel

U.T.S., KSI:

144

Notch Factor

2.6 K_t

Plotted Points:

276

Runouts:

25

No. of References:

1

SUMMARY DATA SHEET
METALS FATIGUE TESTS

Search No. 521

Graph 1B

Reference Code Nos.:	* 001		
Material:	AMS 6415 (AISI 4340) Steel		
Melting Practice:	Electric Furnace		
Heat Treatment:	Normalized	1600 ^o F, 1.5 Hr.	AC
	Austenitized	1525 ^o F, 1.5 Hr.	OQ
	Tempered	1150 ^o F, 4 Hrs.	AC
Yield Strength, KSI:	132		
Elongation:	21%, Gage length not specified		
Hardness:	R _c 32		
Surface Condition:	Longitudinal Polishing		
Surface Finish:	5 Microinch		
Primary Fabrication:	Hot Rolled		
Secondary Operation:	Lathe Turned		
Specimen Type:	Notched bars over 0.125" thick. V-notch, 60 ^o flank angle		
Cyclic Speed:	167 CPS		

*See Reference list for complete identification of reference documents.

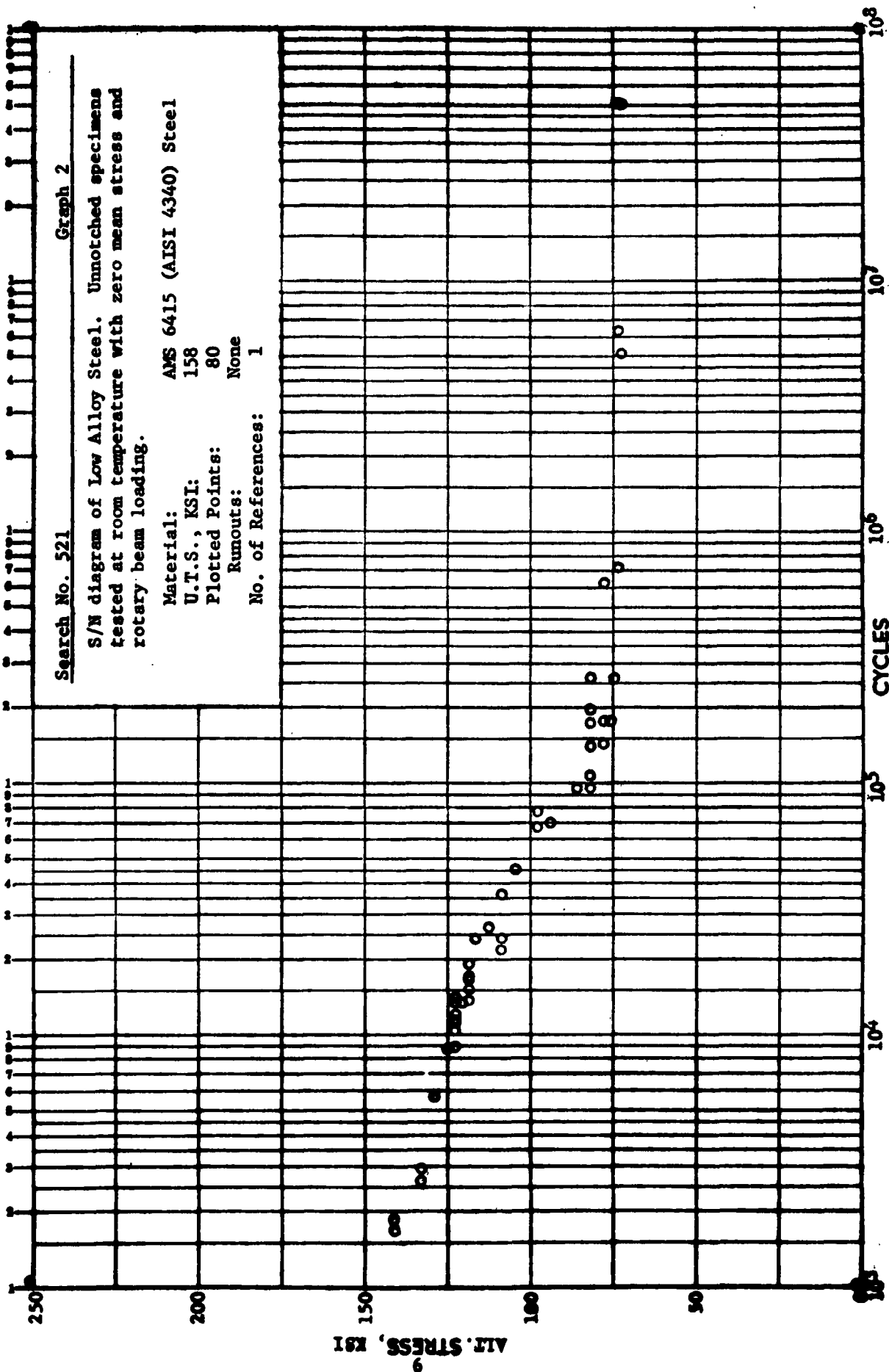
AUTOMATIC DATA ANALYSIS

Search No. 521

Graph 2

S/N diagram of Low Alloy Steel. Unnotched specimens tested at room temperature with zero mean stress and rotary beam loading.

Material: AMS 6415 (AISI 4340) Steel
 U.T.S., KSI: 158
 Plotted Points: 80
 Runouts: None
 No. of References: 1



SUMMARY DATA SHEET
METALS FATIGUE TESTS

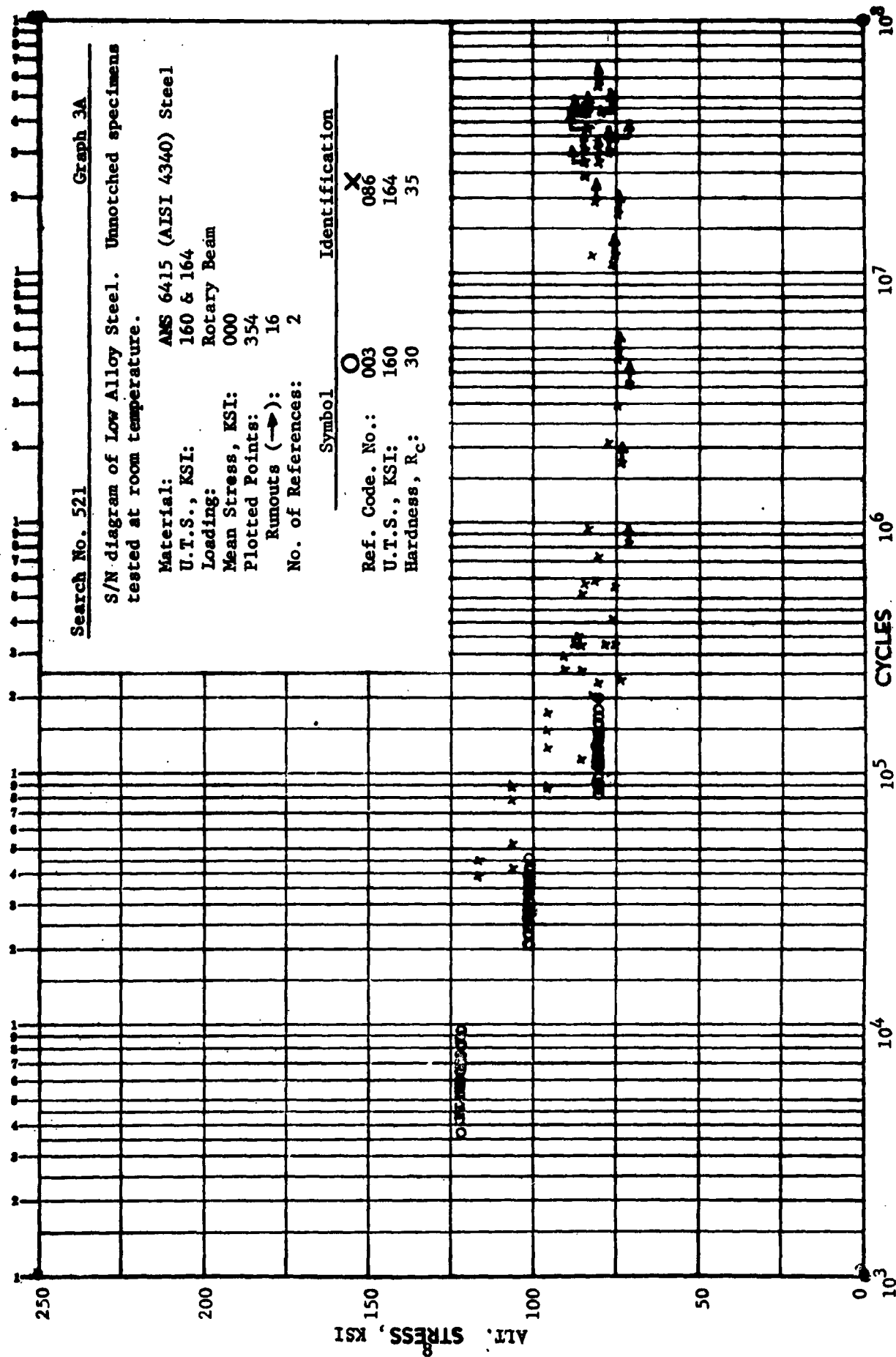
Search 521

Graph 2

Reference Code Nos.:	* 030	
Material:	AMS 6415 (AISI 4340) Steel	
Melting Practice:	Not Recorded	
Heat Treatment:	Normalized	1600°F, 2 Hrs.
	Austenitized	1500°F, 2 Hrs.
	Tempered	1150°F, 4 Hrs.
	and	
	Not Recorded	
Yield Strength, KSI:	138	
Elongation:	Not Recorded	
Hardness:	R _c 30	
Surface Condition:	Longitudinal Polishing	
Surface Finish:	4 Microinch	
Primary Fabrication:	Hot Rolled	
Secondary Operation:	Lathe Turned	
Specimen Type:	Unnotched bars over 0.125" thick	
Cyclic Speed, CPS:	57.5	

*See Reference list for complete identification of reference documents.

AUTOMATIC DATA ANALYSIS



SUMMARY DATA SHEET
METALS FATIGUE TESTS

Search No. 521

Graph 3A

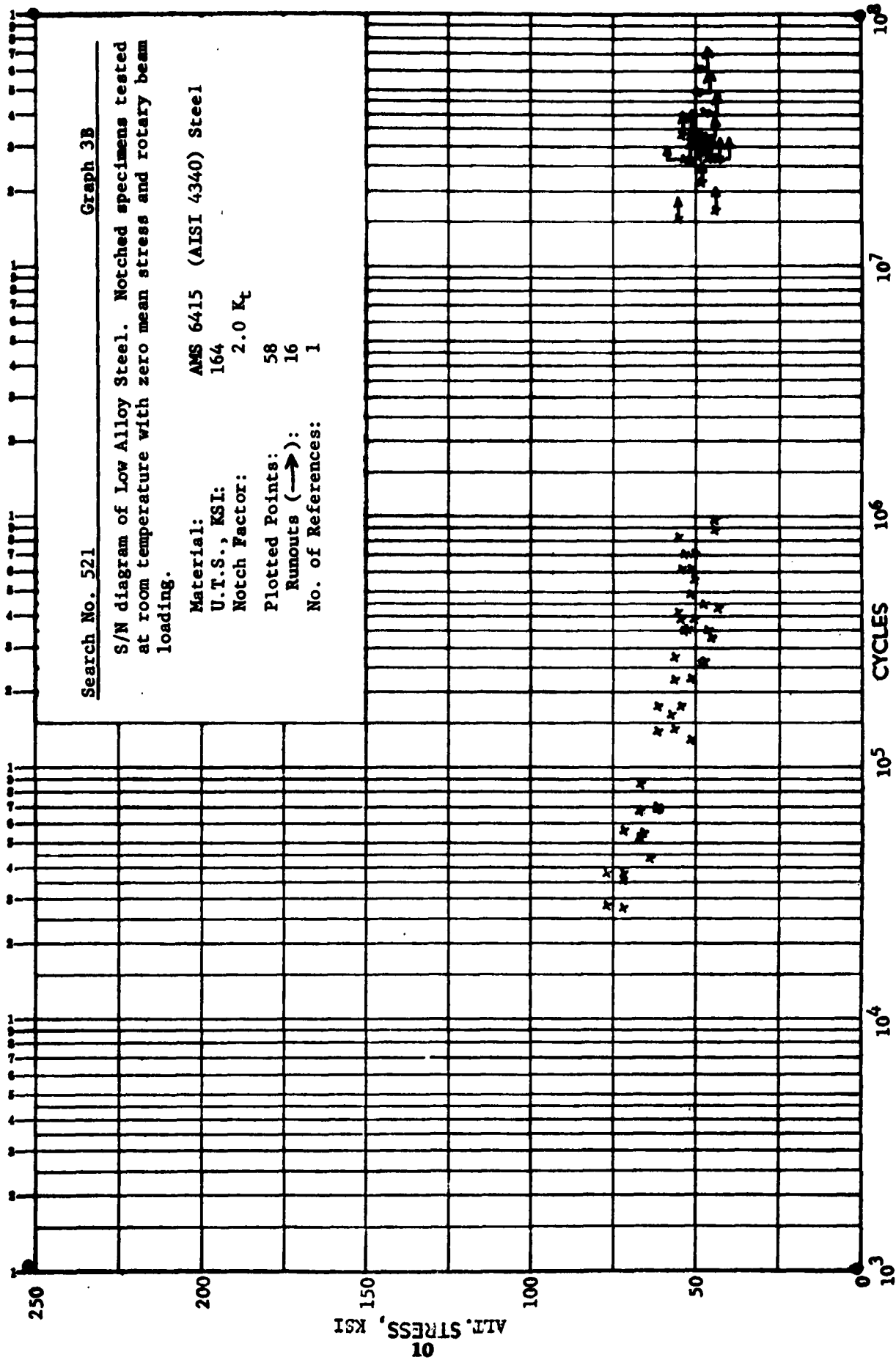
Reference Code Nos.:	* 003 & 086
Material:	AMS 6415 (AISI 4340) Steel
Surface Condition:	Longitudinal Polishing
Surface Finish:	Not Recorded
Primary Fabrication:	Hot Rolled
Secondary Operation:	Lathe Turned
Specimen Type:	Unnotched Bars over 0.125" thick

Additional Symbol Identification

	○	×
Melting Practice:	Electric Furnace	Not Recorded
Heat Treatment:	Austenitized 1525°F, 0.Q. Tempered 1010°F, 1 Hr.	Not Recorded
Elongation:	Not Recorded	16%, 2" Gage
Yield Strength, KSI:	138	156
Cyclic Speed, CPS:	33 & 167	63.3

*See Reference list for complete identification of reference documents.

AUTOMATIC DATA ANALYSIS



SUMMARY DATA SHEET
METALS FATIGUE TESTS

Search No. 521

Graph 3B

Reference Code Nos.:	* 086
Material:	AMS 6415 (AISI 4340) Steel
Melting Practice:	Electric Furnace
Heat Treatment:	Austenitized 1525°F, OQ Tempered 1010°F, 1 Hr.
Yield Strength, KSI:	156
Elongation:	16%, 2" Gage
Hardness:	R _c 35
Surface Condition:	Longitudinal Polishing
Surface Finish:	Not Recorded
Primary Fabrication:	Hot Rolled
Secondary Operation:	Lathe Turned
Specimen Type:	Notched bars over 0.125" thick. Circular notch, flank angle 0°
Cyclic Speed, CPS:	135 & 163

*See Reference list for complete identification of reference documents.

AUTOMATIC DATA ANALYSIS

Search No. 521

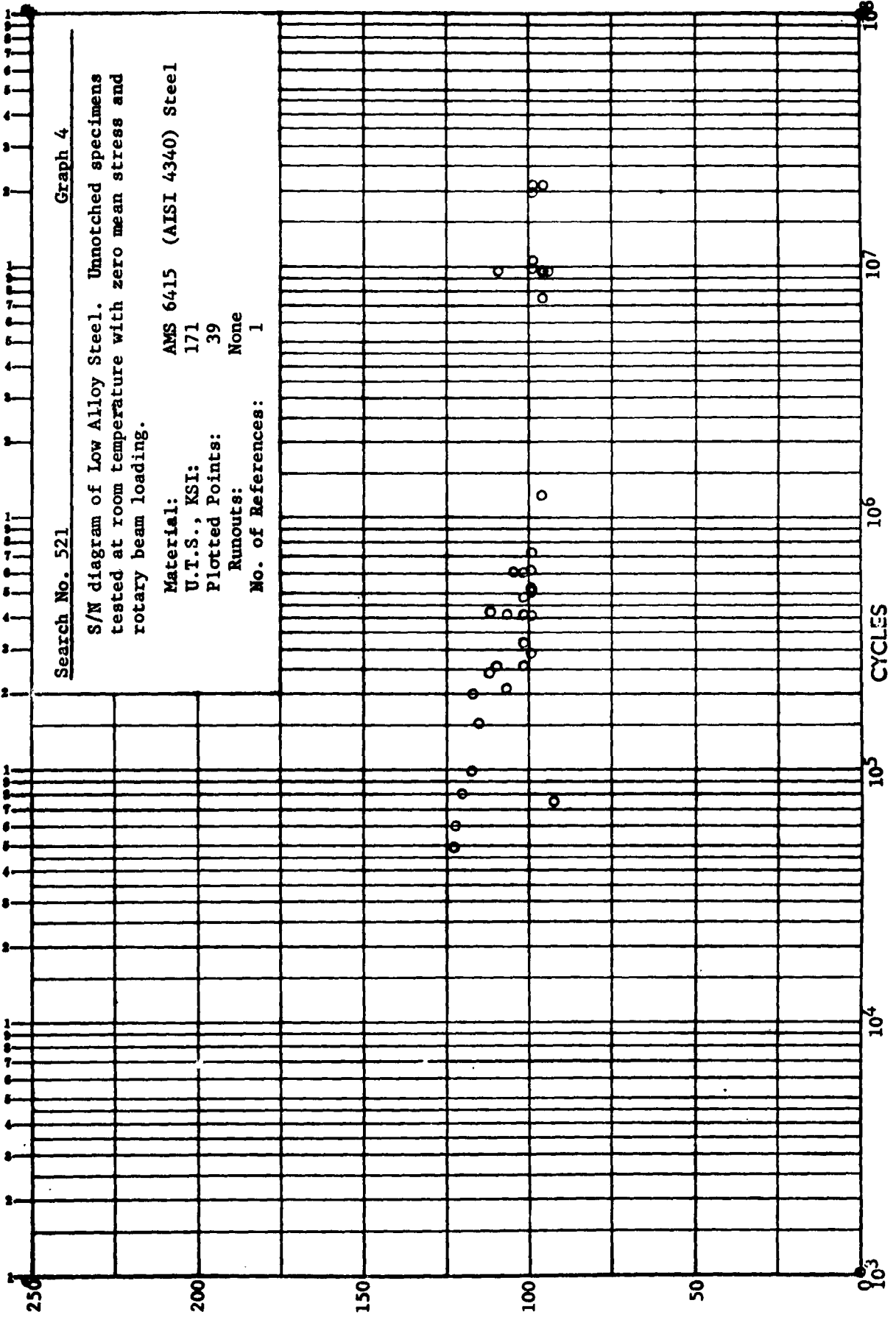
Graph 4

S/N diagram of Low Alloy Steel. Unnotched specimens tested at room temperature with zero mean stress and rotary beam loading.

Material: AMS 6415 (AISI 4340) Steel
 U.T.S., KSI: 171
 Plotted Points: 39
 Runouts: None
 No. of References: 1

ALT. STRESS KSI

12



SUMMARY DATA SHEET
METALS FATIGUE TESTS

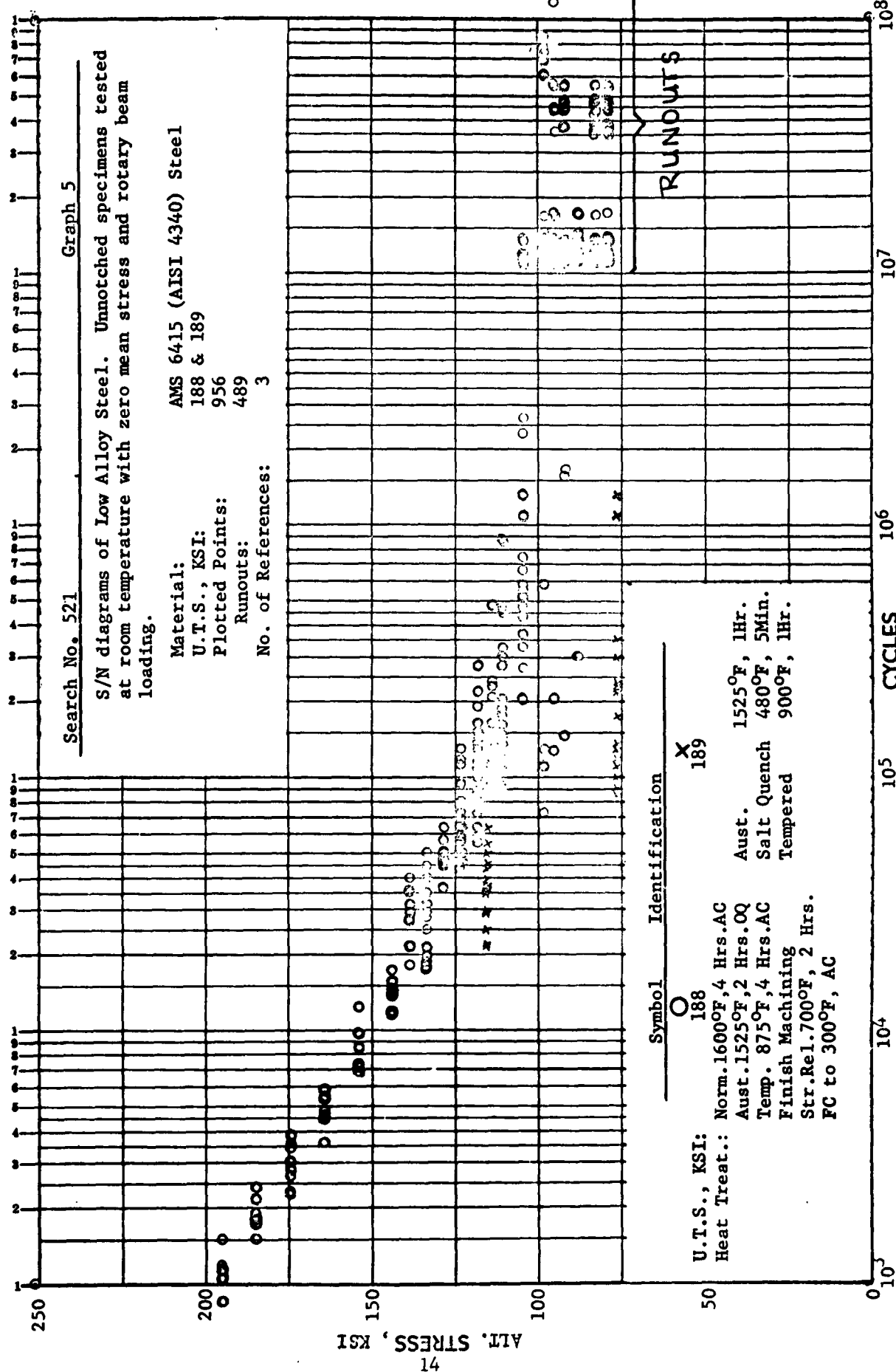
Search No. 521

Graph 4

Reference Code Nos.:*	095
Material:	AMS 6415 (AISI 4340) Steel
Melting Practice:	Electric Furnace
Heat Treatment:	Normalized - 1600 ^o F, 1 Hr.
Elongation:	15%, Gage Length not specified
Hardness:	Not Recorded
Surface Condition:	Longitudinal Polishing
Surface Finish:	Not Recorded
Primary Fabrication:	Hot Rolled
Secondary Operation:	Machined (no details)
Specimen Type:	Unnotched Bars over 0.125" thick
Cyclic Speed, CPS:	125

*See Reference list for complete identification of reference documents.

AUTOMATIC DATA ANALYSIS



SUMMARY DATA SHEET
METALS FATIGUE TESTS

Search No. 521

Graph 5

Material: AMS 6415 (AISI 4340) Steel
Specimen Type: Unnotched bars over 0.125" thick

	<u>Additional Symbol Identification</u>	
	○	×
Reference Code Nos.:	087 & 098	060
Melting Practice:	Vacuum Furnace	Not Recorded
Yield Strength, KSI:	170 & 172	Not Recorded
Elongation:	14%, 2" Gage	Not Recorded
Hardness:	R _c 37	Not Recorded
Surface Condition:	Mechanical Polish	Mech. Polish- Electroplated
Surface Finish:	1 & 5 Microinch	10 Microinch or Not Recorded
Primary Fabrication:	Hot Rolled or Not Recorded	Not Recorded
Secondary Operation:	Lathe Turned or Not Recorded	Mech. Polish- Ni Cd Plated
Cyclic Speed, CPS:	2 & 183	167

*See Reference list for complete identification of reference documents.

Search No. 521

Graph 6

S/N diagram of Low Alloy Steel. Unnotched specimens tested at room temperature with zero mean stress and rotary beam loading.

Material: AMS 6415 (AISI 4340) Steel
U.T.S., KSI: 191 & 192
Plotted Points: 635
Runouts: 208
No. of References: 4

Symbol Identification

Heat Treatment: Norm. 1600°F, 4Hrs, AC
Aust. 1525°F, 2Hrs, OQ
Temp. 875°F, 4Hrs, AC
Finish Machining
Str. Rel. 700°F
F.C. to 300°F, AC

16

ALT. STRESS, KSI

250
200
150
100
50
0

10³ 10⁴ 10⁵ 10⁶ 10⁷ 10⁸

CYCLES

RUNOUTS

Graph 6

S/N diagram of Low Alloy Steel. Unnotched specimens tested at room temperature with zero mean stress and rotary beam loading.

Material:	AMS 6415 (AISI 4340) Steel
U.T.S., KSI:	191 & 192
Plotted Points:	635
Runouts:	208
No. of References:	4

Symbol Identification

x

Heat Treatment:	Norm. 1600°F, 4Hrs, AC	Norm. 1600°F, 4Hrs, AC
	Aust. 1525°F, 2Hrs, OQ	Aust. 1525°F, 2Hrs, OQ
	Temp. 875°F, 4Hrs, AC	Temp. 875°F, 4Hrs, AC
	Finish Machining	Finish Machining
	Str. Rel. 700°F	Str. Rel. 700°F
	F.C. to 300°F, AC	F.C. to 300°F, AC

Runouts

SUMMARY DATA SHEET
METALS FATIGUE TESTS

Search No. 521

Graph 6

Material: AMS 6415 (AISI 4340) Steel
Specimen Type: Unnotched bars 0.125" thick

Additional Symbol Identification

	○	×
Reference Code Nos.:*	001 & 117	67 & 98
Melting Practice:	Electric Furnace	Electric Furnace or Not Recorded
Yield Strength, KSI:	184	180 & 184
Elongation:	15%, 2" Gage	15%, 2" Gage
Hardness:	R _C 40, 41	R _C 40 or Not Recorded
Surface Condition:	Mechanical Polish	Mech.Pol. or Not Recorded
Surface Finish:	5 Microinch	5 Microinch
Primary Fabrication:	Hot Rolled	Extruded or Hot Rolled
Secondary Operation:	Ground or Mech.Pol.	Lathe Turned or Not Rec.
Cyclic Speed, CPS:	167 & 184	183 & 200

*See Reference list for complete identification of reference documents.

AUTOMATIC DATA ANALYSIS

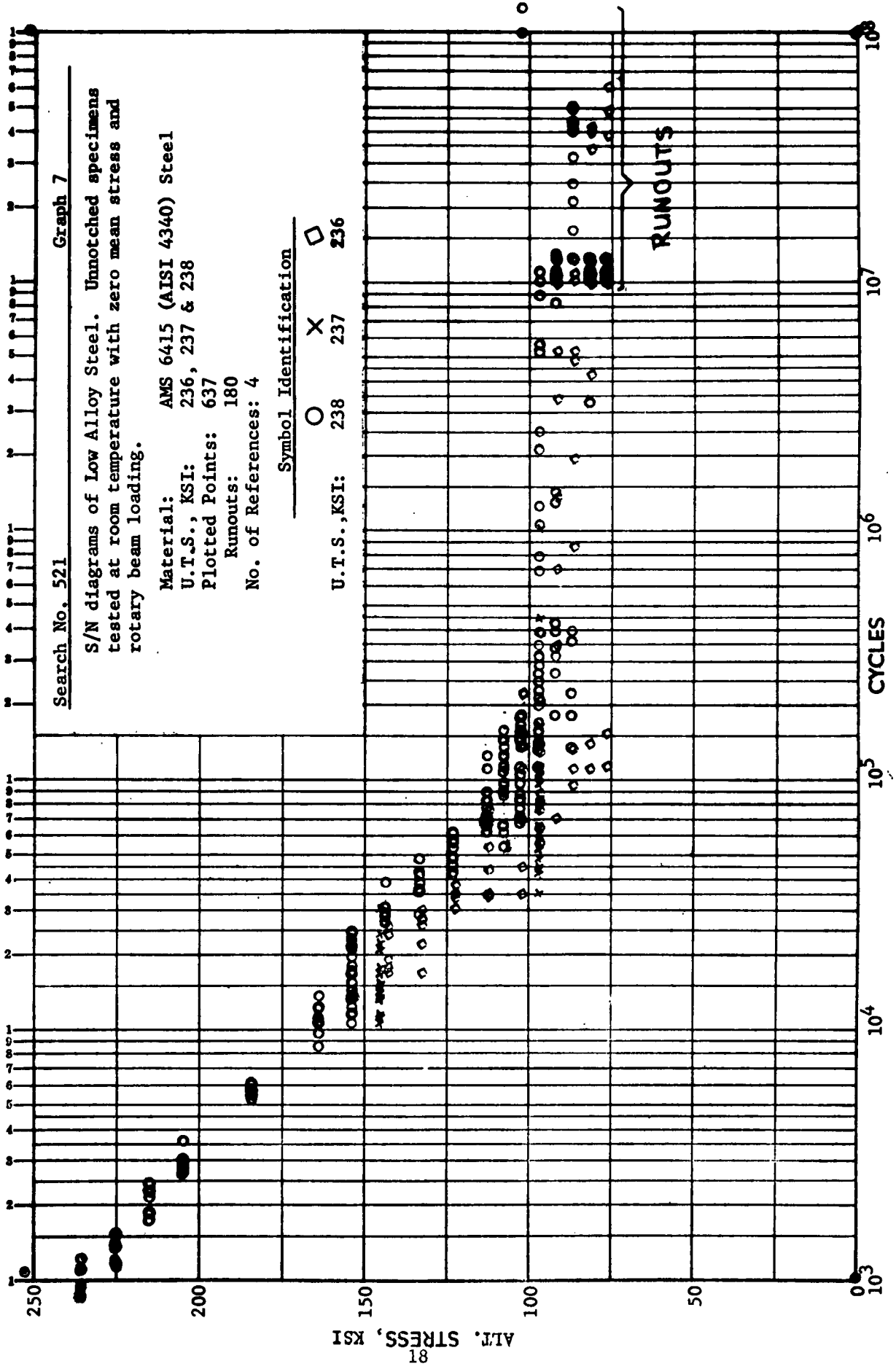
Search No. 521

Graph 7

S/N diagrams of Low Alloy Steel. Unnotched specimens tested at room temperature with zero mean stress and rotary beam loading.

Material: AMS 6415 (AISI 4340) Steel
 U.T.S., KSI: 236, 237 & 238
 Plotted Points: 637
 Runouts: 180
 No. of References: 4

Symbol Identification
 U.T.S., KSI: ○ 238 × 237 □ 236



SUMMARY DATA SHEET
METALS FATIGUE TESTS

Search No. 521

Graph 7

Material: AMS 6415 (AISI 4340) Steel
Specimen Type: Unnotched bars over 0.125" thick

Symbol Identification			
	○	×	◇
Reference Code Nos.:	* 087 & 098	060	067
Melting Practice:	Elec. Furnace or Not Recorded	Not Recorded	Not Recorded
Heat Treatment:	Norm. 1600°F, 2Hrs. AC Aust. 1525°F, 1.5Hr. OQ Temp. 650°F, 4Hrs. AC Finish Machining Str. Rel. 500°F, 4Hrs.	Aust. 1525°F, 1Hr. Salt Q. 480°F, 5Min. Temp. 700°F, 1Hr.	Norm. 1600°F, 4Hrs. Aust. 1525°F, 2Hrs. OQ Temp. 650°F, 4Hrs. Str. Rel. 550°F FC to 400°F, AC
Yield Strength, KSI:	230 or 233	Not Recorded	212
Elongation:	11% or 12%, 2" Gage	Not Recorded	9%, 2" Gage
Hardness:	R _C 42 or 49	Not Recorded	Not Recorded
Surface Condition:	Mechanical Polish	Mech. Polish- Electroplated	Mech. Polish
Surface Finish:	1 & 5 Microinch	10 Microinch	5 Microinch
Primary Fabrication:	Hot Rolled or Not Recorded	Not Recorded	Forged
Secondary Operation:	Lathe Turned or Not Recorded	Mech. Pol. & Plated	Not Recorded

*See Reference list for complete identification of reference documents.

AUTOMATIC DATA ANALYSIS

Search No. 521

Graph 8

S/N diagram of Low Alloy Steel. Unnotched specimens
tested at room temperature with zero mean stress
and rotary beam loading.

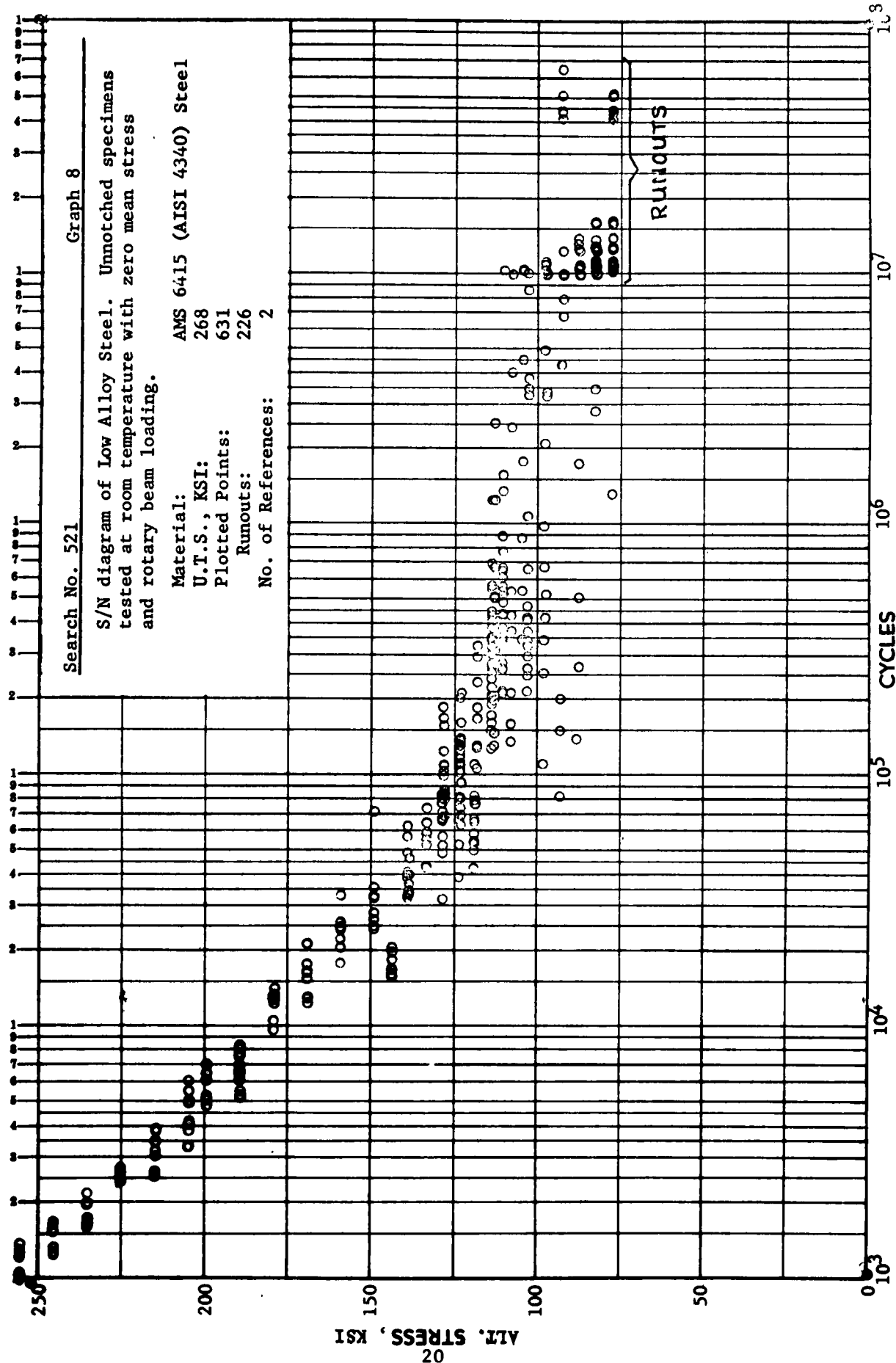
Material: AMS 6415 (AISI 4340) Steel

U.T.S., KSI: 268

Plotted Points: 631

Runouts: 226

No. of References: 2



SUMMARY DATA SHEET
METALS FATIGUE TESTS

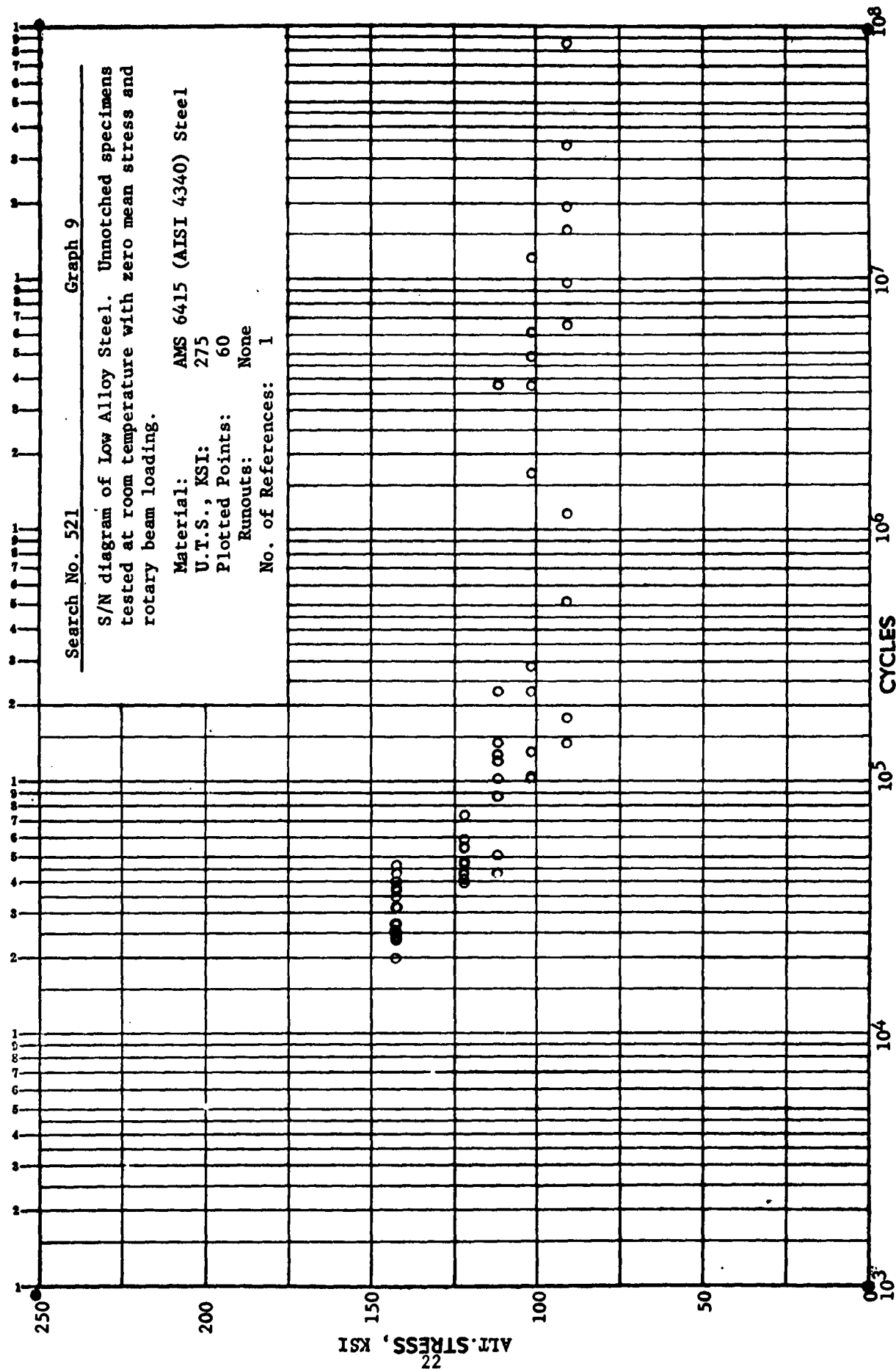
Search 521

Graph 8

Reference Code Nos.:	* 001 & 117
Material:	AMS 6415 (AISI 4340) Steel
Melting Practice:	Electric Furnace
Heat Treatment:	Norm. 1600°F, 4 Hrs. AC Aust. 1475°F, 4 Hrs. OQ Stab. 450°F, 8 Hrs. AC Temp. 250°F, 24 Hrs. AC
Yield Strength:	250 KSI
Elongation:	11%, gage length not specified
Hardness:	R _C 53 & 56
Surface Condition:	Longitudinal Polishing
Surface Finish:	5 Microinch
Primary Fabrication:	Hot Rolled
Secondary Operation:	Ground Surface
Specimen Type:	Unnotched bars over 0.125" thick
Cyclic Speed, CPS:	2.1, 167, 184

*See Reference list for complete identification of reference documents.

AUTOMATIC DATA ANALYSIS



ALT. STRESS, KSI

CYCLES

SUMMARY DATA SHEET
METALS FATIGUE TESTS

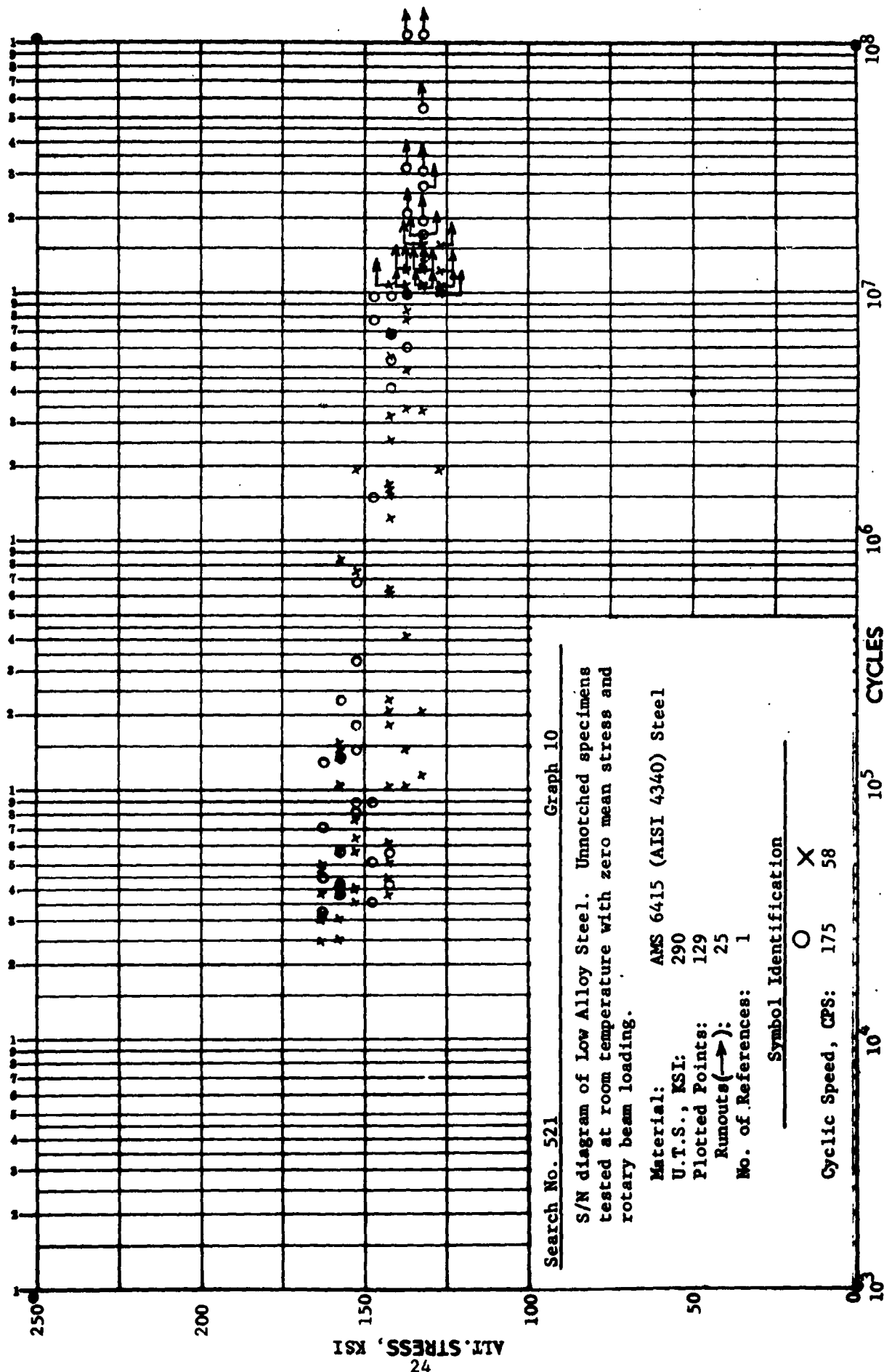
Search No. 521

Graph 9

Reference Code Nos.:	* 041
Material:	AMS 6415 (AISI 4340) Steel
Melting Practice:	Electric Furnace
Heat Treatment:	Austenitized 1550°F, Salt Bath 20 Min. OQ at 120°F to 150°F Tempered 400°F, 4 Hrs.
Yield Strength; KSI:	Not Recorded
Elongation:	14%, 2" Gage
Hardness:	R _c 50
Surface Condition:	Mechanical Polishing
Surface Finish:	3 Microinch
Primary Fabrication:	Forged
Secondary Operation:	All Surface Ground
Specimen Type:	Unnotched Bars over 0.125" thick
Cyclic Speed, CPS:	58

*See Reference list for complete identification of reference documents.

AUTOMATIC DATA ANALYSIS



SUMMARY DATA SHEET
METALS FATIGUE TESTS

Search No. 521

Graph 10

Reference Code Nos.:	* 041
Material:	AMS 6415 (AISI 4340) Steel
Melting Practice:	Vacuum Furnace
Heat Treatment:	Austenitized 1550°F, Salt Bath 20 Min. OQ at 120°F to 150°F Tempered 400°F, 4 Hrs.
Yield Strength, KSI:	Not Recorded
Elongation:	Not Recorded
Hardness:	R _c 51
Surface Condition:	Mechanical Polishing
Surface Finish:	3 Microinch
Primary Fabrication:	Forged
Secondary Operation:	All Surfaces Ground, Mechanical Polish
Specimen Type:	Unnotched bars over 0.125" thick

*See Reference list for complete identification of reference documents.

REFERENCES ----- SEARCH NO. 521

Reference Code Number	Reference
001	Cummings, H.N., Stulen, F.B., and Schulte, W.C., "Investigation of Materials, Fatigue Problems Applicable to Propeller Design", WADC Technical Report 54-531 (May 1955)
003	Starkey, W.L., "Vibration Fatigue Studies", Annual Report Part I, Rept #3 on Cont.# AF 33(616)-259, The Ohio State Univ. Research Foundation.E.O. #R-591-80 SR-1e(Sept. 1953)
030	Marco, S.M., Starkey, W.L., Foster, T.G., "Fatigue Characteristics of SAE 4340 Steel; The Effects of Sequential Loading on SAE 4340 Steel", The Ohio State University, AMC Contract No. AF 33(039)-12393, Report No. 2 (Oct. 9, 1951)
041	Fisher, J.I., Sheehan, J.P.; "The Effect of Metallurgical Variables on the Fatigue Properties of AISI 4340 Steel Heat Treated in the Tensile Strength Range 260,000-310,000 PSI". WADC TR 58-289.
060	Brookes, R., Schowalter, L.U., Juergens, R.J.; "Effect of Diffused Nickel-Cadmium Plating on the Fatigue Strength of 4340 Steel". McDonnell Aircraft Report Number 5462 (June 1957)
067	Cummings, H.N., Stulen, F.B., Schulte, W.C.; "Research on Ferrous Materials Fatigue". WADC TR 58-43 (August 1958)
086	Dolan, T.J., Hanley, B.C., "The Effect of Size of Specimen on the Fatigue Strength of SAE 4340 Steel". Engineering Experiment Station, University of Illinois (May 1948)
087	Cummings, H.N., Stulen, F.B., Schulte, W.C.; "Investigation of Materials Fatigue Problems". Curtiss-Wright Corporation Propeller Division, Caldwell, New Jersey (March 1957)
095	Brook, G.W.; Sinclair, G.M.; "An Investigation of Fatigue Characteristics of Leaded Alloy Steel". University of Illinois, T. & AM Report No. 105 (September 1956)
098	Cummings, H.N.; "Investigation of Materials Fatigue Problems". Curtiss-Wright Corporation, Contract No. AF 33(616)2876, Report Numbers 1 to 10 (April 1955 through October 1956)
117	Cummings, H.N., Stulen, F.B., Schulte, W.C.; "Investigation of Materials Fatigue Problems Applicable to Propeller Design". WADC TR 54-531 Supplement 1 (October 1955)